International Journal Of Advance Research, Ideas And Innovations In Technology

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 12, Issue 5 - V12I5-1160)
Available online at: https://www.ijariit.com

Effect of Brain Gym Exercises on Postural Balance and Health-Related Quality of Life in School-Going Hearing-Impaired Children: An Experimental Study

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ABSTRACT

***Background:** Children with sensorineural hearing loss often have impaired Balance and postural instability issues occur because of the shared inner ear pathology. Brain Gym exercises combine cross body movements that helps in cross-lateral sensory processing in the brain which may improve postural stability, moreover limited clinical evidence exist regarding its effectiveness in hearing impaired children.*

***Objective:** To compare the effect of Brain Gym exercises against standard physical exercises for static, dynamic balance and health-related quality of life (HRQoL) in hearing-impaired school going children.*

***Methods:** 30 students (age 10–15 years, hearing loss > 40 dB, Pediatric Balance Scale score < 52) were recruited through purposive sampling from special schools in Vadodara and assigned to Group A (Brain Gym, n=15) or Group B (General Physical Exercises, n=15). Both groups were given exercise protocol for 35–40 minutes per session, 3 days a week for 4 weeks. Outcomes measured were static balance (Flamingo Balance Test), dynamic balance (Y-Balance Test composite score), and quality of life (Pediatric Quality of Life Inventory 4.0).*

***Results:** Both groups showed statistically significant within-group improvements ($p < 0.001$), Group A achieved greater gains. Fall attempts during Flamingo test decreased significantly more in Group A compared to Group B (Right: $t = 2.16$, $p = 0.03$; Left: $t = 2.31$, $p = 0.02$). Group A also showed greater improvement in Y-Balance Test composite reach (Right: $t = 6.25$, $p < 0.001$; Left: $t = 4.96$, $p < 0.001$) and overall PedsQL scores ($t = 6.18$, $p < 0.001$).*

***Conclusion:** Incorporating Brain Gym exercises into pediatric rehabilitation of deaf children substantially impacts postural control and quality of life than general physical exercises alone.*

***Keywords:** Hearing Impairment, Brain Gym, Static Balance, Dynamic Balance, Quality of Life, Pediatric Rehabilitation*

1. INTRODUCTION

Hearing sensation is one of the primary sensations through which human beings navigate, perceive and respond to their surrounding environment. it also helps us in spatial awareness and warn us of any hazard in the environment. [1]. In India alone, over 63 million people live with significant hearing loss [2]. Worldwide there are hundreds of millions of children with hearing deficits exceeding 50 to 85 decibels, these deficits hinder physical and cognitive growth during their crucial years of development [3].

In Hearing impaired children, along with communication problems these deficits isolate them from their learning environment, delays speech and language development, affects their academic progress, and compromise emotional well-being [4]. Pathologically, there are two types of hearing loss: conductive hearing loss (CHL) typically caused by outer or middle ear issues like chronic otitis media and sensorineural hearing loss (SNHL) caused by damage to the delicate cochlear hair cells, vestibulocochlear nerve fibers, or central auditory pathways [6,7].

The anatomy of the human ear has a relation directly to physical balance. The membranous inner ear contains both the sound-processing cochlea and the vestibular complex (the semicircular canals and otolith organs that detect head rotation and linear acceleration) [8]. Microscopic hair cells present in the inner ear convert mechanical movement into electrical signals sent through the eighth cranial nerve. when there is damage or development affection to the inner it affects the vestibular system also [9,14]. As a result, children with sensorineural hearing loss suffer from vestibular hypofunction, which directly impairs their balance [15].

Postural stability is maintained with real-time coordination from the central nervous system and inputs from visual, somatosensory, and the vestibular system [13]. When inner-ear fails to send proper feedback to the central processing, children become heavily dependent on their visual and proprioceptive inputs. This imbalance affects their balance, social and physical activity, causing them to frequent tripping, clumsiness, and an increased risk of fall [14].

Postural instability combined with communication barriers often keep these children away from sports and social activities. The resulting isolation leads to anxiety, low self-esteem, and lower overall quality of life [10,11,19]. Standard physical education classes or training doesn't offer targeted sensorimotor integration in hearing-impaired students.

Developed by Paul and Gail Dennison, Brain Gym exercises is a movement-based protocol built involving cross-lateral physical tasks, breathing, and sensory stimulation [16]. Exercises like Cross Crawl, Hook-Ups, and Lazy 8s stimulate cross-hemispheric communication through the corpus callosum [17]. By doing exercises that require coordination of both the sides improve bilateral motor coordination, feedback loops which helps to improve spatial orientation, attention, coordination, and reduce stress [18]. While earlier studies have evaluated effect of Brain Gym in children with Down syndrome and autism, empirical research on its impact on balance and quality of life in hearing impaired children remains limited [24,25]. This study is aimed to directly investigates effect of Brain Gym exercise protocol against general physical exercises in hearing impaired children.

1.1 Aim and Specific Objectives

Aim: To evaluate the effect of Brain Gym exercises on static balance, dynamic balance, and health-related quality of life in school-going hearing-impaired children.

Specific Objectives:

- To determine the effect of Brain gym exercises on static balance using the Flamingo Balance Test.
- To determine the effect of Brain gym exercises on dynamic balance using the multi-directional Y-Balance Test (YBT).
- To Assess the effect of Brain gym exercises on health-related quality of life by using the Pediatric Quality of Life Inventory (PedsQL 4.0 Child Report).
- To Compare effect of respective outcomes between the Brain Gym protocol and general physical exercises.

1.2 Hypothesis

- Null Hypothesis (H_0): There is no significant effect of brain gym exercises on balance and quality of life in school going hearing impaired children
- Alternate Hypothesis (H_1): There is significant effect of brain gym exercises on balance and quality of life in school going hearing impaired children

2. REVIEW OF LITERATURE

1. Goda et al. (2024) studied 32 children with Down syndrome (aged 6–12) and found that combining Brain Gym exercises with balance training produced significantly greater improvements in Single Leg Stance, Timed Up and Go, and Pediatric Balance Scale scores than balance training alone [24].

2. Clara et al. (2023) assessed a Brain Gym intervention protocol of 4 weeks in 10 children with Autism Spectrum Disorder, found significant gains on Bruininks-Oseretsky motor subtests [25].

3. Jecinth et al. (2017) conducted a 45-day trial study in 30 hearing-impaired high school students. outcome measure testing Post-intervention using the Stroop Color-Word Test and Coopersmith Self-Esteem Inventory showed improvements in sensory processing speed and self-esteem [26].

4. Tanaya et al. (2018) investigated a 15-day Brain Gym intervention protocol among psychiatric patients, finding significant improvements in WHOQOL-BREF scores and self-esteem and reduction in psychological distress [27].

5. Sember et al. (2020) validated the Flamingo Balance Test for pediatric static balance assessment, demonstrating test-retest reliability (ICC=0.88–0.92) in pre-adolescent children [28].

6. Lee et al. (2012) established high test-retest reliability for the Y-Balance Test (YBT) across anterior, posteromedial, and posterolateral directions (ICC = 0.91–0.96) in primary school children, supporting its use as a reliable dynamic balance assessment [29].

7. Hendriksma et al. (2020) confirmed strong psychometric agreement between pediatric self-report and parent proxy-report versions of the PedsQL 4.0 inventory (ICC = 0.917–0.972) in children with sensory deficits, validating its diagnostic accuracy [30].

3. MATERIALS AND METHODOLOGY

3.1 Study Design & Setting

This study is a single-blinded, randomized comparative experimental design. The study was conducted across special education schools for hearing-impaired children in Vadodara, Gujarat, India, over a 12-month period. Ethical clearance was formally granted by the Institutional Review Board of Pioneer Physiotherapy College (Proposal No: PPC/OW/686F/2024). Standard informed consent was obtained from school directors, and written assent was secured from all parents/legal guardians prior to enrollment.

3.2 Sample Size Estimation

Sample size calculations were performed using G*Power software (version 3.1.9.4). Based on preliminary pilot data for the primary outcome measure (Flamingo test mean change = 1.7, SD = 1.18), with an alpha level set at 0.05 (95% confidence interval) and statistical power (1 - β) set at 0.90, the minimum sample size required was determined to be 30 participants (15 per group).

3.3 Participant Selection Criteria

Inclusion Criteria

•Chronological age between 10 and 15 years (both males and females).
•Documented moderate-to-profound sensorineural hearing loss (> 40 dB in the better hearing ear).
• Baseline Pediatric Balance Scale (PBS) score < 52, indicating mild-to-moderate balance deficit.
•Written parental assent and willingness of the child to participate.

Exclusion Criteria

• Associated neurological, visual, or intellectual impairments (e.g., cerebral palsy, severe visual deficit, mental retardation).
• Presence of cochlear implants or active usage of advanced bone-anchored hearing aids during testing.
• Orthopedic deformities, recent lower extremity injuries, or uncompensated cardiopulmonary disorders.
• Acute systemic illness or fever (> 1 week duration).

3.4 Outcome Measures & Instrumentation

1. Flamingo Balance Test (Static Balance): assesses single-leg postural control on a narrow wooden beam (50 cm length x 3 cm width x 4 cm height). Participants balance on their dominant single leg while flexing the other knee. The outcome recorded is the total number of fall attempts required to maintain balance for a cumulative 60-second duration. Lower trial counts reflect superior static stability [28].

2. Y-Balance Test (YBT) (Dynamic Balance): Assesses dynamic single-leg postural reach in three directions: Anterior (ANT), Posteromedial (PM), and Posterolateral (PL). Reach distances were normalized to lower extremity limb length (measured from anterior superior iliac spine to medial malleolus). Composite reach scores were calculated using the standard formula: Composite Score(%)=[(ANT+PM+PL)/(3xLimbLength)]x100 Higher composite scores represent greater dynamic stability [29].

3. Pediatric Quality of Life Inventory (PedsQL 4.0 Child Report): A 23-item standardized questionnaire having four functional domains: Physical Health (8 items), Emotional Functioning (5 items), Social Functioning (5 items), and School Functioning (5 items). Items are rated on a 5-point Likert scale and converted to a 0–100 scale. Higher scores indicate superior HRQoL [30].

3.5 Intervention Protocols

Participants were randomly assigned into two parallel groups. Both groups underwent 35–40-minute treatment sessions, 3 days per week for 4 consecutive weeks.

Experimental Group (Group A - Brain Gym Exercises): Received 26 core Brain Gym movements (3 repetitions per movement per session), lateral crossing movements, lengthening activities, energy exercises, and deepening attitudes. Key exercises included Cross Crawl, Sit-Up Cross Crawl, Lazy 8s, Alphabet 8s, The Elephant, Brain Buttons, Earth Buttons, Balance Buttons, Space Buttons, The Owl, Thinking Cap, Gravity Glider, and Positive Points [16,32]. Exercises were visually demonstrated by an experienced physical therapist in present of an sign language expert at the school.

Control Group (Group B - General Physical Exercises): Received a standardized general physical conditioning program (physical exercises) comprising continuous low-impact aerobic activity (5 minutes of progressive warm-up walking), functional play therapy routines (skipping, bear walking, crawling for 15 minutes), and structured callisthenic exercises (Jumping on place, Jumping jacks, Scissor jumps, Butterfly breathing, and High knees; 2 sets of 15 repetitions each) [33,34].

4. RESULTS AND STATISTICAL ANALYSIS

Statistical analysis was conducted using SPSS software (version 30.0). Shapiro-Wilk tests confirmed normal data distribution across all variables ($p > 0.05$). Baseline demographic data was verified using independent sample t-tests. Within-group pre- to post-intervention changes were assessed using paired t-tests, while between-group therapeutic differences were analyzed using independent sample t-tests at a 95% confidence interval (alpha level = 0.05).

Table 1: Baseline Demographic and Clinical Characteristics

Baseline Parameter	Group A: Brain Gym (n=15)	Group B: General Ex (n=15)	p-value
Age (Years) (Mean ± SD)	12.27 ± 1.33	12.07 ± 1.28	0.678 (NS)
Pediatric Balance Scale (PBS)	46.13 ± 3.16	46.00 ± 3.14	0.909 (NS)

NS = Not Significant (p > 0.05). Data indicates equivalent baseline clinical profiles across groups.

Table 2: Within-Group Pre- and Post-Intervention Comparison for Group A (Brain Gym Exercises)

Outcome Measure	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	t-value	p-value	Inference
Flamingo Right (Attempts)	6.13 ± 1.80	2.80 ± 1.14	9.597	< 0.001	Highly Significant
Flamingo Left (Attempts)	6.00 ± 1.55	2.73 ± 1.03	9.885	< 0.001	Highly Significant
YBT Composite Right (%)	76.21 ± 5.87	83.44 ± 5.59	-17.446	< 0.001	Highly Significant
YBT Composite Left (%)	76.25 ± 6.08	83.30 ± 5.59	-13.560	< 0.001	Highly Significant
PedsQL Total Score	47.46 ± 7.33	55.00 ± 7.72	-21.520	< 0.001	Highly Significant

Paired t-test results demonstrate highly significant within-group improvements across static balance, dynamic balance, and HRQoL in the Brain Gym cohort.

Table 3: Within-Group Pre- and Post-Intervention Comparison for Group B (General Physical Exercises)

Outcome Measure	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	t-value	p-value	Inference
Flamingo Right (Attempts)	6.53 ± 1.59	4.13 ± 1.50	9.431	< 0.001	Highly Significant
Flamingo Left (Attempts)	6.46 ± 1.30	4.13 ± 1.24	10.044	< 0.001	Highly Significant
YBT Composite Right (%)	76.02 ± 6.09	79.85 ± 5.51	-10.876	< 0.001	Highly Significant
YBT Composite	76.91 ± 6.13	80.90 ± 5.52	-11.964	< 0.001	Highly

Left (%)					Significant
PedsQL Total Score	47.33 ± 7.27	51.60 ± 7.95	-10.774	< 0.001	Highly Significant

General physical exercises also generated statistically significant within-group improvements, reflecting general conditioning effects.

Table 4: Between-Group Comparison of Mean Change Scores (Post - Pre) Between Group A and Group B

Outcome Measure	Group A Mean Change	Group B Mean Change	t-value	p-value	Inference
Flamingo Right Change	3.33 ± 1.34	2.40 ± 0.98	2.160	0.030	Statistically Significant
Flamingo Left Change	3.26 ± 1.27	2.33 ± 0.89	2.310	0.020	Statistically Significant
YBT Right Change (%)	7.23 ± 1.60	3.83 ± 1.36	6.250	< 0.001	Highly Significant
YBT Left Change (%)	7.05 ± 2.01	3.98 ± 1.29	4.960	< 0.001	Highly Significant
PedsQL Total Change	7.53 ± 1.35	4.26 ± 1.53	6.180	< 0.001	Highly Significant

Independent sample t-tests demonstrate superior therapeutic gains in the Brain Gym exercise cohort across all functional outcome parameters.

5. DISCUSSION

This study compared the effectiveness of Brain Gym exercises versus general physical conditioning on static, dynamic balance, and health-related quality of life among school-going hearing-impaired children. The primary findings of this study showed functional benefits in both the groups. Brain Gym exercise group showed statistically superior gains across all assessed outcomes.

Children with sensorineural hearing loss frequently suffers peripheral vestibular damage as the auditory and vestibular organs share the membranous labyrinth [8,15]. This leads to impaired postural control, increased postural sway, and delayed motor skill acquisition [35,36]. in this study static balance improvements were observed through the Flamingo test (reductions of 3.33 and 3.26 attempts on right and left limbs, respectively, in Group A) signifies increased postural control capacity. Brain Gym exercises such as Cross Crawl and Balance Buttons require cross-lateral sensory integration, activates both cerebral hemispheres across the corpus callosum and improving proprioceptive feedback [17,37]. This increased proprioceptive processing effectively compensates for underlying vestibular deficits.

Dynamic balance, measured via composite reach on the YBT, showed significant progress in the Brain Gym group (+7.23% right, +7.05% left) compared to the general physical exercise group (+3.83% right, +3.98% left). Exercises that involve directional shifts, head movements, and trunk rotation such as The Elephant, The Owl, and Lazy 8s stimulate central pattern generators and cerebellar motor refinement [38,39]. These complex movements enhances neuromuscular coordination, and automatic postural responses during activities involving dynamic weight-shifting [40,41].

Crucially, the marked improvement in HRQoL scores (PedsQL mean score increase of +7.53 points in Group A vs. +4.26 points in Group B) demonstrates the secondary benefits of enhanced motor control. Motor confidence directly facilitates peer communication, physical play, and active inclusion in recreational activities [19,43]. Furthermore, routines incorporating deep breathing and neurovascular point activation (e.g., Belly Breathing, Positive Points, and Hook-Ups) help in relaxing the nervous system by reducing sympathetic nervous system hyperactivity, alleviating stress, lowering performance anxiety, and optimizing cognitive attention span [27,42].

6. CLINICAL IMPLICATIONS

- Brain Gym exercises represent an accessible, low-cost, non-invasive therapeutic exercise that can be effortlessly integrated into special school pediatric physiotherapy programs.
- Fall Prevention & Safety: Enhancing static and dynamic balance reduces fall risks, functional fatigue, and accidental injuries among hearing-impaired children during daily academic and physical activities.
- Holistic Well-Being: Combining physical repatterning with stress-relieving breathing techniques addresses both physical performance and emotional regulation, boosting confidence and self-efficacy.

7. CONCLUSION

Brain Gym exercises are significantly more effective than general physical conditioning in improving static balance, dynamic balance, and health-related quality of life in school-going hearing-impaired children. Adding these exercises into neuro-rehabilitation or as a part of routine physical activity will help the hearing impaired children to reduce balance impairments and enhance holistic development of the children.

8. LIMITATIONS AND FUTURE RECOMMENDATIONS

Limitations:

•The study was done on relatively small sample size (n = 30) which limits generalizability to broader pediatric population.

•The 4-week intervention period did not evaluate long-term benefits of the intervention

• The assessors who measured the outcomes were not blinded.

Future Recommendations:

• In future longitudinal randomized controlled trials testing children across schools of different regions with extended follow-up periods (6–12 months) can be done.
• Compare Brain Gym exercises with other treatment techniques like vestibular rehabilitation therapy (VRT) and virtual reality-based balance training.
• Cognitive markers like attention span, and neuroimaging can be studied alongside balance outcomes in hearing impaired population

9. ACKNOWLEDGEMENT

The authors express sincere gratitude to the administrators, teachers, parents, and students of participating special schools for their support and cooperation during this study.

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